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METHOD AND DEVICE FOR PRODUCING CONTINUOUSLY CAST STEEL SLABS

The invention concerns a method and a device for producing slabs in a continuous casting installation, with an oscillating casting mold and a downstream strand guide below it, in which the cast strand is bent from the vertical casting direction into the horizontal rolling direction and during this process is supported and conveyed by driver rolls, which are arranged opposite each other in pairs, are adjusted relative to each other with well-defined contact force and can be combined into segments, and is deformed by at least one pair of driver rolls to a thickness that is reduced relative to its cast state, after which the continuous preliminary section or the reduced strand is cut into slabs, which are conveyed to a soaking furnace and then to a rolling mill.

So that the cast strand, which is produced in a continuous casting installation with a thickness of less than 100 mm, can be conveyed out of the continuous casting installation, the driver rolls are pressed against the strand with a certain

pressure which prevents the driver rolls from slipping through and produces a sufficiently large tensile force on the strand below the point of complete solidification. In the state of the art, this pressure of the driver rolls in the area of complete solidification or locally sooner is utilized to alter the strand thickness, since the rolling forces to be applied are small due to the fact that the cast strand is still soft.

For example, DE 38 22 939 C1 describes a continuous casting method for the production of slabs with a reduced thickness relative to the cast state, in which a strand whose cross section is partially solidified is deformed by rolls that can be hydraulically adjusted relative to each other. These rolls acts to deform the strand both within the solidification section and in the area of the completely solidified strand, and during this process, the strand is deformed from about 60 mm to a final gage of 20 to 15 mm, and at the same time a product with a high proportion of rolling microstructure is produced. In this regard, at least one pair of rolls that acts on the already completely solidified part of the strand can be adjusted against stops to ensure the final dimension of the strand.

DE 198 17 034 A1 describes a method for the continuous

casting of thin metal strip in a continuous casting installation with an oscillating, water-cooled mold, in which, directly after the complete solidification of the cast strand, at least one pair of driver rolls is continuously pressed against the strand with a variably defined pressure to achieve a well-defined thickness reduction of at least 2% and to maintain a desired strand thickness that has been adjusted in advance at a constant level.

Finally, EP 0 804 981 B1 describes a continuous casting method and a continuous casting device, in which cast slabs are fed to a large number of reducing installations, each of the reducing installations is assigned a target rolling reduction or a target pressure, and a deformation of a liquid core of the slabs is carried out, such that cast slabs can be produced with increased or decreased thickness compared to the slabs continuously removed from the mold.

In addition to the effort to reduce the thickness of the cast strand inexpensively and with relatively simple means that are already available by using the drivers that are already present, another objective that needs to be pursued is improvement of the surface quality of the slabs that are produced. In their cast state, continuously cast products may

have surface defects, such as oscillation marks and other microstructural inhomogeneities. Subsequent rolling of the slab into a strip then results in defects in the strip surface. The effect of oscillation marks in austenitic steels consists essentially in the fact that, at the base of the oscillation marks (in the notch), there is diminished heat dissipation, which results in coarsening of the microstructure and segregation. These are mainly Cr or Mo concentrations. These concentrations lead to the formation of intermetallic phases, which, as the cause of the specified surface defects, must be removed by grinding before the rolling operation is carried out.

The solidification behavior of austenites is characterized by shrinkage during the transformation from ferrite to austenite, which results in a tendency of the strand shell to contract. This contraction can lead to increased delta ferrite concentrations and to poorer hot workability in the affected places. The nonuniform solidification at the surface then causes so-called scale patterns during direct rolling. These negative phenomena also generally have to be eliminated by grinding.

In ferritic steels as well, oscillation marks cause

diminished heat dissipation at their base, which results in coarsening of the microstructure and segregation (Ni concentration, hard spots). To obtain a satisfactory final product, these inhomogeneities must also be eliminated by grinding.

The aforementioned surface defects cannot be eliminated by the previously known deformation of the cast strand while it is still soft, since the practical effect is to "knead" especially the oscillation marks that are present more deeply into the soft cast strand.

Proceeding on the basis of this prior art, the objective of the invention is to specify a simple method and a device based on this method, by means of which the surface working, e.g., grinding, that was previously required can be eliminated.

The objective with respect to the method is achieved by the features specified in the characterizing clause of Claim 1, and the objective with respect to the device is achieved by the features specified in the characterizing clause of Claim 9, in accordance with which the cast strand, while it is still within the continuous casting installation in the area of the bending or straightening driver rolls after its complete solidification, is deformed by at least one reducing stand at an early point in

time, at a temperature that is still so high, and in such a well-defined way with high energy input that

- the depth of the oscillation marks present in the surface of the cast strand is reduced, and
- as a result of the release of the energy introduced into the reduced strand during this deformation, the finely crystalline surface zone is enlarged, and in the subsequent heat treatment in a soaking furnace, increased recrystallization occurs with the grains in the deformed surface zone of the slab becoming finer.

This positive effect of a deformation carried out at an early point in time with high energy input, especially in the surface zone of the cast strand, by which the recrystallization during the subsequent heat treatment in a soaking furnace is favorably influenced and by which the oscillation marks are smoothed down at an early point in time, so that the heat flow over the strand surface can occur uniformly, is preferably obtained at a surface temperature of the cast strand on the order of 1,000°C.

In accordance with the invention, this deformation, by which subsequent surface working, for example, by grinding is reduced to a minimum, is carried out with one or more reducing

stands with roll diameters of 600 to 900 mm, and preferably with a roll diameter of 700 mm, for the reduction of a cast strand 50 mm thick by a maximum amount of 7 mm.

To be able to maintain extremely narrow tolerance limits in the hot rolled strip, slabs of very exact geometry are required in the rolling mill. Therefore, to realize an exactly defined slab format, the rolls of the reducing stand are provided with preshaping, and the reducing stand or stands are provided with an automatic gage control system and are connected with the downstream rolling mill for feedback of the rolling parameters to be set. When several reducing stands are used, only a slight reduction of the cast strand with high dimensional accuracy of the desired preliminary section is carried out with the last pair of rolls. These measures then already make it possible to produce a cast strand with exactly adjusted geometric data and improved surface in the continuous casting installation, so that slabs that do not first have to be subjected to expensive surface working can be supplied to the subsequent hot rolling mill.

To carry out the method of the invention, at least one reducing stand is installed within the continuous casting installation in the area of the bending or straightening driver

rolls. In this regard, depending on existing spatial conditions, the following items can be provided:

• At least one additional reducing stand after the straightening drivers with column or lever construction.

• At least one additional reducing stand before the straightening drivers with column or lever construction; realization depends very strongly on spatial conditions (casting radius of the continuous casting installation, point of complete solidification).

• Realization of the straightening driver as a combination of straightening driver and reducing stand. In this regard, the surface deformation of the cast strand can be carried out in as many steps as there are pairs of rolls available.

Additional details, features, and advantages of the invention are apparent from the following explanation of the specific embodiments of the invention schematically illustrated in the drawings.

-- Figure 1 shows a flow diagram of a continuous casting installation with soaking furnace.

-- Figures 2a-2c show the microstructural development of the cast strand or the slab during the various process steps of Figure 1.

-- Figure 3 shows a continuous casting plant with reducing stand with column construction after the straightening drivers.

-- Figure 4 shows a continuous casting installation with reducing stand with lever construction after the straightening drivers.

-- Figure 5 shows a continuous casting installation with straightening drivers converted to a reducing stand.

Figure 1 shows the process steps that are relevant to the invention in a continuous casting installation, specifically, the production of the cast strand 12 in an oscillating mold 11, deformation of the cast strand 12 in a reducing stand 30 to form a reduced strand 12', and heat treatment of the reduced strand 12', which has been cut into slabs 12'', in a soaking furnace 40.

The cast strand 12 that has been produced leaves the oscillating mold 11 in the vertical direction, is bent into the horizontal strand conveyance direction 13, and supplied as a continuous cast strand 12 to a reducing stand 30, where the deformation in accordance with the invention occurs, by which a reduced strand 12' with the desired surface qualities is produced. After separation of the reduced strand 12' into slabs 12'', the slabs are subjected to a heat treatment in a soaking

furnace 40 before being fed into the rolling mill (the rolling mill is not shown). The microstructural forms of the cast strand or slab that are obtained in each of these various process steps of Figure 1 are shown schematically in vertical sections in Figures 2a-2c.

The cast strand 12 produced in the mold 11 has a cast microstructure 14 (Figure 2a) with a finely crystalline surface zone 18 produced during the complete solidification of the cast strand 12. The strand surface 16 contains oscillation marks 17, which are represented as notch-like depressions. They were produced during the casting process in the mold and cause, among other things, the aforementioned surface defects during the subsequent rolling process. These oscillation marks 17 were largely smoothed down by the deformation, in accordance with the invention, of the cast strand 12 in the reducing stand 30 to form the thickness-reduced cast strand or reduced strand 12' (Figure 2b), so that now only relatively small depressions 17' are still present in the strand surface 16'. In addition, during this deformation of the cast strand 12, the original finely crystalline structure of the surface zone 18 was partially recrystallized in a small inner zone 19 by the introduction into the deformed surface zone 18' of a higher

energy state, whose effect extends as far as the region of the aligned dendrites. During the subsequent heat treatment of the slabs 12'' in the soaking furnace 40 (Figure 2c), this recrystallized zone 19 was then able to expand into the completely recrystallized surface zone 19'.

In Figures 3, 4, and 5, different reducing stands 30 are installed in an existing continuous casting installation 10. For the sake of clarity, each drawing shows the same continuous casting installation 10, and for this reason the same parts of the installation were also provided with the same reference numbers. The cast strand 12 produced in the oscillating mold (not shown here) of the continuous casting installation 10 is initially guided vertically downward. It is supported by pairs of rolls of a vertical strand guide 20 and conveyed by driver rolls 21. In the bending zone 22, the cast strand 12 is bent out of the vertical casting direction into the horizontal conveyance direction 13 and conveyed in the rolling direction in a strand guide 23 by means of straightening drivers 24. A cutting device 25, which is installed some distance from the straightening drivers 24, cuts the cast strand or reduced strand 12' into slabs 12'' of the desired length as it passes through. The cutting device 25 is followed by the parts of the

installation which were referred to earlier but are no longer shown here, namely, the soaking furnace 40 and rolling mill.

In Figure 3, two additional reducing stands 30a with column construction are installed in the space available between the straightening drivers 24 and the cutting device 25 of the continuous casting plant 10, and the cast strand 12 is deformed into the reduced strand 12' in these reducing stands. The two reducing stands 30a are designed significantly larger than the otherwise customary drivers, and their rolls 31 (600-900 mm in diameter in accordance with the invention) are significantly larger in diameter than the rolls of the strand guide. This ensures the desired energy input into the cast strand 12 during the deformation that is carried out with surface smoothing (reduction of the depth of the oscillation marks).

In Figure 4, two reducing stands 30b with lever construction are installed in the same place in the continuous casting installation 10 instead of the reducing stands 30a of Figure 3. Here again, the reducing stands 30b and their rolls 31 are dimensioned significantly larger than the otherwise customary drivers of the strand guide.

In Figure 5, no additional reducing stands are provided in the continuous casting installation 10. The deformation of the cast strand 12 in accordance with the invention is carried out by original straightening drivers 24 that have been converted to a reducing stand 30c and that are likewise dimensioned significantly larger than the otherwise customary straightening drivers 24 (see Figures 3 and 4).

The invention is not limited to the illustrated embodiments. Thus, the number of reducing stands 30a, 30b and converted straightening drivers 24 shown in Figures 3 to 5 is merely an example and can be suitably varied by one skilled in the art according to the existing local situation. The same is true of the selection of a suitable type of stand construction and the selection of the site of installation of the stands or the selection of a combination of different installation sites within the continuous casting installation, in which case especially the characteristics of the cast strand must also be taken into consideration.

List of Reference Numbers

10	continuous casting installation
11	mold
12	cast strand
12'	reduced strand
12''	slab
13	strand conveyance direction
14, 14', 14'	primary cast structure
16, 16'	cast strand surface
17, 17'	oscillation marks
18, 18'	finely crystalline surface zone
19, 19'	completely recrystallized surface zone
20	vertical strand guide
21	vertical driver rolls
22	bending zone
23	horizontal strand guide
24	straightening driver
25	cutting device
30	reducing stand
30a	reducing stand with column construction

30b	reducing stand with lever construction
30c	reducing stand as modified straightening driver
31	rolls of 30
40	soaking furnace